1.A method to form a VLSI-photonic heterogeneous system device, said method comprising:

providing an optical substrate comprising at least one passive optical component formed therein;

providing an electronic substrate comprising at least one active electronic component formed therein;

forming a plurality of metal pillars through said optical substrate and protruding out a first surface of said optical substrate;

forming a plurality of metal pads on a first surface of said electronic substrate; and

bonding together said optical substrate and said electronic substrate by a method further comprising:

aligning said first surfaces of said optical and electronic substrates such that said protruding metal pillars contact said metal pads; and

thermally treating said optical and electronic substrates such that said metal pillars bond to said metal pads.

2.The method according to Claim 1 wherein said optical

substrate is a wafer comprising a plurality of die, wherein each said die comprises at least one said passive optical component, wherein said electronic substrate is a wafer comprising a plurality of die, and wherein each said die comprises at least one said active electronic component.

3. The method according to Claim 2 wherein said optical wafer and said electronic wafer each contain alignment marks so that said wafers can be accurately aligned one to another.

4. The method according to Claim 1 wherein said electronic substrate comprises a photodetector device, wherein said optical substrate transmits an optical signal, and wherein a vertical waveguide transmits said optical signal through said electronic substrate to said photodetector device.

5. The method according to Claim 1 wherein said passive optical component is a waveguide, a splitter, a multiplexer, a demultiplexer, an add/drop filter, a ring resonator, ~~or~~ a waveguide optical switch, or a combination thereof.

6. The method according to Claim 1 wherein said passive optical component is a thin film, a Si-based waveguide, a silica waveguide, a photonic crystal, or combinations thereof.

7. The method according to Claim 1 wherein said active electronic component is a Si modulator, a trans-impedance amplifier, a clock recovery circuit, a laser driver circuit, a multiplexing circuit, a demultiplexing circuit, a radio frequency processing circuit, a baseband processing circuit, or a combination thereof.

8. The method according to Claim 1 wherein said step of thermally treating is performed at a temperature of between about 100 °C and about 500 °C.

9. The method according to Claim 8 wherein said step of bonding together further comprises a pre-plasma surface treatment of said protruding metal pillars and said metal pads prior to said step of thermally treating.

10. The method according to Claim 1 wherein said passive optical component comprises a waveguide and wherein said waveguide further comprises an embedded mirror.

11.The method according to Claim 10 wherein said electronic substrate comprises:

a vertical waveguide; and

a photodetector device such that an optical signal path is formed through said optical substrate waveguide, to said embedded mirror, through said electronic substrate vertical waveguide, and to said photodetector.

12.The method according to Claim 11 wherein said vertical waveguide and said optical substrate waveguide comprise the same material.

13.The method according to Claim 10 wherein said embedded mirror is formed by a method comprising:

forming a cladding layer overlying a silicon layer on said optical substrate;

patterning said cladding layer to form openings through said cladding layer where said embedded mirror is planned;

depositing a waveguide layer overlying said cladding layer and filling said openings;

patterning said waveguide layer to define said waveguide wherein said patterning forms an angled edge

where said waveguide layer is etched through to underlying said cladding layer;

depositing a metal layer overlying said waveguide; and

patterning said metal layer to remove said metal layer from said waveguide excepting at said angled edge of said waveguide wherein said metal layer forms an embedded mirror for said waveguide.

14.The method according to Claim 13 wherein said step of patterning said cladding layer and said step of patterning said metal layer use the same photolithographic mask.

15.The method according to Claim 13 further comprising depositing a second cladding layer overlying said waveguide.

16.The method according to Claim 15 wherein said second cladding layer comprises a thickness of less than about 5,000 Å such that chemical or biological agents contacting said second cladding layer will affect evanescent light when an optical signal is transmitted in said waveguide.

17. The method according to Claim 15 wherein said waveguide has parallel trenches or is based on a photonic crystal

device and wherein chemical or biological agents will be trapped in said trenches or in holes in said waveguide or photonic crystal device to thereby affect evanescent light when an optical signal is transmitted in said waveguide.

18. The method according to Claim 1 wherein said optical substrate comprises a silicon layer and a dielectric layer, wherein said dielectric layer contains said passive optical component, and wherein said dielectric layer is at said first surface, and further comprising removing said silicon layer from said dielectric layer after said step of bonding together said optical substrate and said electronic substrate.

19. The method according to Claim 1 wherein said optical substrate comprises a thick dielectric layer and further comprising:

depositing a metal layer overlying said thick dielectric layer on the surface opposite said electronic substrate after said step of bonding together; and

patterning said metal layer to form metal lines.

20.The method according to Claim 19 wherein said metal lines form a low loss transmission line, an inductor, or an antenna.

21.The method according to Claim 19 wherein said thick dielectric layer has a thickness of between about 10 μm and about 50 μm.

22.The method according to Claim 1 wherein said passive optical component comprises a waveguide and further comprising:

patterning said optical substrate to form an opening through a part of said waveguide after said step of bonding together; and

placing a laser diode in said opening such that light from said laser diode will enter said waveguide.

23.The method according to Claim 22 wherein said waveguide further comprises an embedded mirror and wherein said electronic substrate comprises:

a vertical waveguide; and

a photodetector device such that said laser diode light will be transmitted through said optical substrate

waveguide, to said embedded mirror, through said electronic substrate vertical waveguide, and to said photodetector.

24.The method according to Claim 1 further comprising:

etching said optical substrate after said step of bonding together such that said metal pillars protrude out of said optical substrate at a second surface opposite said electronic substrate;

providing a third substrate with metal pads on a first surface; and

bonding together said optical substrate and said third substrate by a method further comprising:

aligning said second surface of said optical substrate and said first surface of said third substrate such that said protruding metal pillars contact said metal pads; and

thermally treating said optical and third substrates such that said metal pillars bond to said metal pads.

25.The method according to Claim 24 wherein said third substrate comprises either an electronic substrate comprising at least one active electronic component formed therein or an optical substrate comprising at least one

passive optical component formed therein.

26.A method to form a waveguide with an embedded mirror in the manufacture of an optical substrate device, said method comprising:

forming a cladding layer overlying a silicon layer on an optical substrate;

patterning said cladding layer to form openings through said cladding layer where an embedded mirror is planned;

depositing a waveguide layer overlying said cladding layer and filling said openings;

patterning said waveguide layer to define a waveguide wherein said patterning forms an angled edge where said waveguide layer is etched through to underlying said cladding layer;

depositing a metal layer overlying said waveguide; and

patterning said metal layer to remove said metal layer from said waveguide excepting at said angled edge of said waveguide wherein said metal layer forms an embedded mirror for said waveguide.

27.The method according to Claim 26 wherein said step of patterning said cladding layer and said step of patterning said metal layer use the same photolithographic mask.

28.The method according to Claim 26 further comprising depositing a second cladding layer overlying said waveguide.

29.The method according to Claim 26 wherein said second cladding layer comprises a thickness of less than about 5,000 Å such that chemical or biological agents contacting said second cladding layer will affect evanescent light when an optical signal is transmitted in said waveguide.

30. The method according to Claim 29 wherein said waveguide has parallel trenches or is based on a photonic crystal device and wherein chemical or biological agents will be trapped in said trenches or in holes in said waveguide or photonic crystal device to thereby affect evanescent light when an optical signal is transmitted in said waveguide.

31.A VLSI- photonic heterogeneous system device, said device comprising:

an optical substrate comprising:

at least one passive optical component formed therein; and

a plurality of metal pillars through said optical substrate and protruding out a first surface of said optical substrate; and

an electronic substrate comprising:

at least one active electronic component formed therein; and

a plurality of metal pads on a first surface of said electronic substrate wherein said first surfaces of said optical substrate and said electronic substrate are held together by the bonding between said metal pillars and said metal pads.

32.The device according to Claim 31 wherein said optical substrate is a wafer comprising a plurality of die, wherein each said die comprises at least one said passive optical component, wherein said electronic substrate is a wafer comprising a plurality of die, and wherein each said die comprises at least one said active electronic component.

33.The device according to Claim 32 wherein said optical wafer and said electronic wafer each contain alignment

marks so that said wafers can be accurately aligned one to another.

34. The device according to Claim 31 wherein said electronic substrate comprises a photodetector device, wherein said optical substrate transmits an optical signal, and wherein a vertical waveguide transmits said optical signal through said electronic substrate to said photodetector device.

35.The device according to Claim 31 wherein said passive optical component comprises a waveguide, a splitter, a multiplexer, a demultiplexer, an add/drop filter, a ring resonator, or a waveguide optical switch.

36.The device according to Claim 31 wherein said active electronic component comprises a Si modulator, a trans-impedance amplifier, a clock recovery circuit, a laser driver circuit, a multiplexing circuit, a demultiplexing circuit, a radio frequency processing circuit, or a baseband processing circuit.

37. The device according to Claim 31 wherein said passive optical component comprises a waveguide and wherein said waveguide further comprises an embedded mirror.

38. The device according to Claim 37 wherein said electronic substrate comprises:

a vertical waveguide; and

a photodetector device such that an optical signal path is formed through said optical substrate waveguide, to said embedded mirror, through said electronic substrate vertical waveguide, and to said photodetector.

39. The device according to Claim 38 wherein said vertical waveguide and said optical substrate waveguide comprise the same material.

40. The device according to Claim 37 wherein said embedded mirror is formed by a method comprising:

forming a cladding layer overlying a silicon layer on said optical substrate;

patterning said cladding layer to form openings through said cladding layer where said embedded mirror is planned;

depositing a waveguide layer overlying said cladding layer and filling said openings;

patterning said waveguide layer to define said waveguide wherein said patterning forms an angled edge where said waveguide layer is etched through to underlying said cladding layer;

depositing a metal layer overlying said waveguide;

patterning said metal layer to remove said metal layer from said waveguide excepting at said angled edge of said waveguide wherein said metal layer forms an embedded mirror for said waveguide; and

depositing a second cladding layer overlying said waveguide.

41.The device according to Claim 40 wherein said second cladding layer comprises a thickness of less than about 5,000 Å such that chemical or biological agents contacting said second cladding layer will affect evanescent light when an optical signal is transmitted in said waveguide.

42. The method according to Claim 40 wherein said waveguide has parallel trenches or is based on photonic crystal device and wherein chemical or biological agents will be trapped in said trenches or in holes in said waveguide or

photonic crystal device to thereby affect evanescent light when an optical signal is transmitted in said waveguide.

43. The device according to Claim 31 wherein said optical substrate further comprises:

a thick dielectric layer; and

patterned metal lines overlying said thick dielectric layer on the surface opposite said electronic substrate.

44. The device according to Claim 43 wherein said patterned metal lines form a low loss transmission line, an inductor, or an antenna.

45. The device according to Claim 44 wherein said thick dielectric layer has a thickness of between about 10 μm and about 50 μm.

46. The device according to Claim 31 wherein said optical substrate further comprises:

a waveguide; and

a laser diode in an opening in said optical substrate and aligned such that that light from said laser diode will enter said waveguide.

47.The device according to Claim 46 wherein said waveguide further comprises an embedded mirror and wherein said electronic substrate comprises:

a vertical waveguide; and

a photodetector device such that said laser diode light will be transmitted through said optical substrate waveguide, to said embedded mirror, through said electronic substrate vertical waveguide, and to said photodetector.

48.The device according to Claim 46 wherein said waveguide is based on a photonic crystal device.

49.The device according to Claim 31 further comprising a third substrate comprising a plurality of metal pads on a first surface of said third substrate wherein a second surface of said optical substrate, opposite from said electronic substrate, and said first surface of said third substrate are held together by the bonding between said metal pillars and said third substrate metal pads.

50.The method according to Claim 49 wherein said third substrate comprises either an electronic substrate comprising at least one active electronic component formed therein or an optical substrate comprising at least one

passive optical component formed therein.

51.A waveguide device with an embedded mirror, said device comprising:

a cladding layer overlying a silicon layer on an optical substrate wherein said cladding layer has openings through to underlying silicon layer;

a patterned waveguide layer overlying said cladding layer and partially filling said openings wherein said patterned waveguide layer has an angled edge in said openings;

a metal layer overlying said waveguide only on said angled edge; and

a second cladding layer overlying said waveguide layer and said metal layer.

52.The device according to Claim 51 wherein said second cladding layer comprises a thickness of less than about 5,000 Å such that chemical or biological agents contacting said second cladding layer will affect evanescent light when an optical signal is transmitted in said waveguide.

53.The method according to Claim 51 wherein said waveguide comprises a photonic crystal material and wherein chemical

or biological agents will be trapped in holes in said photonic crystal material to thereby affect evanescent light when an optical signal is transmitted in said waveguide.